The 2005 Amazon drought legacy effect delayed the 2006 wet season onset

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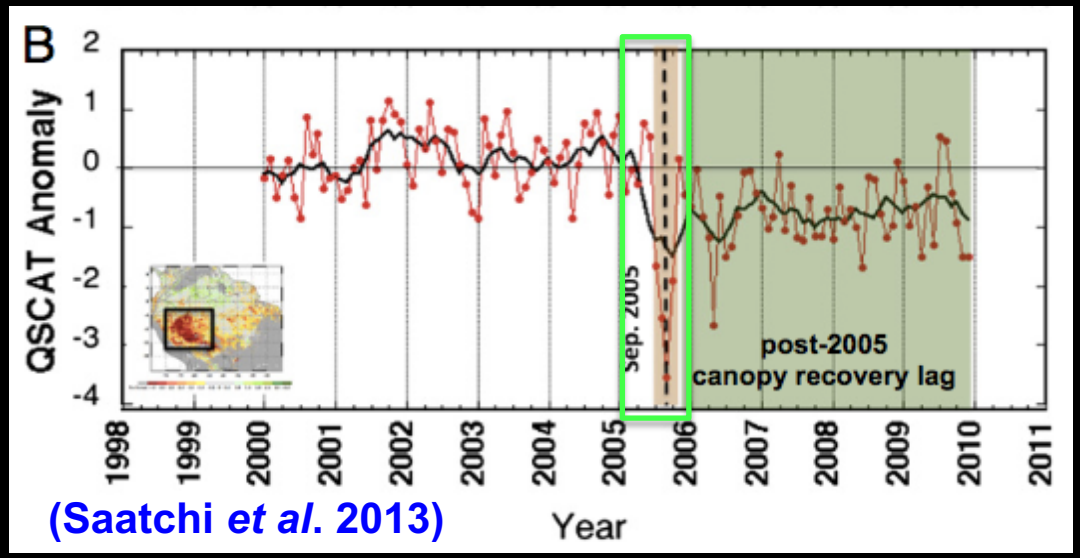
Motivation

Amazonia has been experiencing severe droughts in the recent decades.



The SeaWinds Scatterometer onboard QuikSCAT (QSCAT) captured the long-term impact (i.e., legacy effect) of the 2005 drought in southern Amazonia (4°–12°S, 76–66°W).

Scientific questions

- Does the drought legacy effect on trees influence southern Amazonian wet-season precipitation onset?
- If so, what land–atmosphere feedback processes cause the changes of wet-season onset (WSO) over southern Amazonia?
- *Here, the observed WSO is defined as the first date when the pentad (i.e., 5-day) mean rain rate exceeds the climatological annual mean rain rate of the same rainfall dataset during six out of eight pentad* **(Li and Fu, 2004).**

TRMM shows that the WSO is delayed after the 2005 drought

Year	Pentad	Year	Pentad
2001	59	2009	60
2002	63	2010	61
2003	66	2011	59
2004	64	2012	61
2005	64	2013	55
2006	64	2014	61
2007	58	2015	66
2008	66	Mean	62 ± 3

Hypothesis: Evapotranspiration (ET) variation associated with canopy biomass change triggers the wet season onset delay.

Datasets used in this study

- The atmosphere over the southern Amazon has two main moisture sources: **rainforest ET and ocean evaporation** (Salati *et al*. 1979).
- We study the two water vapor sources from multiple observations over the southern Amazon.

$$P - E + \frac{\partial Q}{\partial t} = -\nabla \cdot (QV)$$

P is precipitation, E is ET, -∇.(QV) is the large-scale water convergence flux (Wong *et al*. 2016).

Datasets	Purpose
Specific humidity and wind speed from ECMWF re-analysis (ERA)	To identity the baseline years with similar atmospheric large-scale water vapor convergence compared to 2006
A precipitation, runoff, and terrestrial water storage based ET product (ET_{OBS})	To evaluate the ET variations of the baseline years
Deuterium retrievals from the Tropospheric Emission Spectrometer (TES)	To separate the ET sources (i.e., local ET or oceanic evaporation) of the baseline years

Observed wet season onset and water vapor dynamics

	ERA Q_{ATMO} (mm month^{-1})	Pentad of wet season onset
2006	**32**	**64**
2003	21	66
2004	22	64
2007	48	58
2009	30	60
2014	55	61
Mean	35±15	62±3

- Q_{ATMO} is calculated by following Wong *et al.* (2016).
- We select baseline years during 2001– 2015 with -6 – 0 pentad (i.e., -30–0 day) $Q_{ATMO} - Q_{ATMO,\ 2006} < 1\sigma$.
- Five years are selected and they are 2003, 2004, 2007, 2009, and 2014.

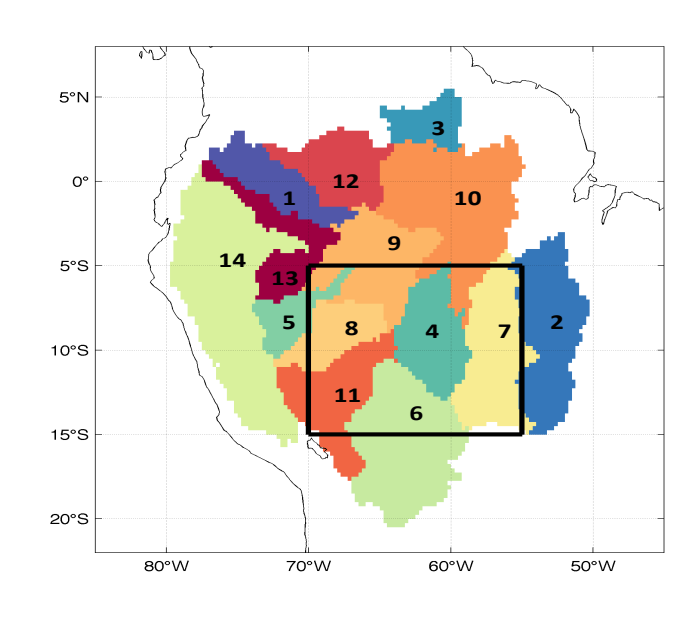
A new ET product

- To better identify the ET variations in the study region, we use a new ET product (i.e., ET_{OBS}).
- Sub-basin ET estimates and associated uncertainties are derived based on 3 precipitation, 3 GRACE retrievals and 14 runoff stations from the ORE_HYBAM network for the 2003–2013 period.

$$ET = P - R - dS/dt$$

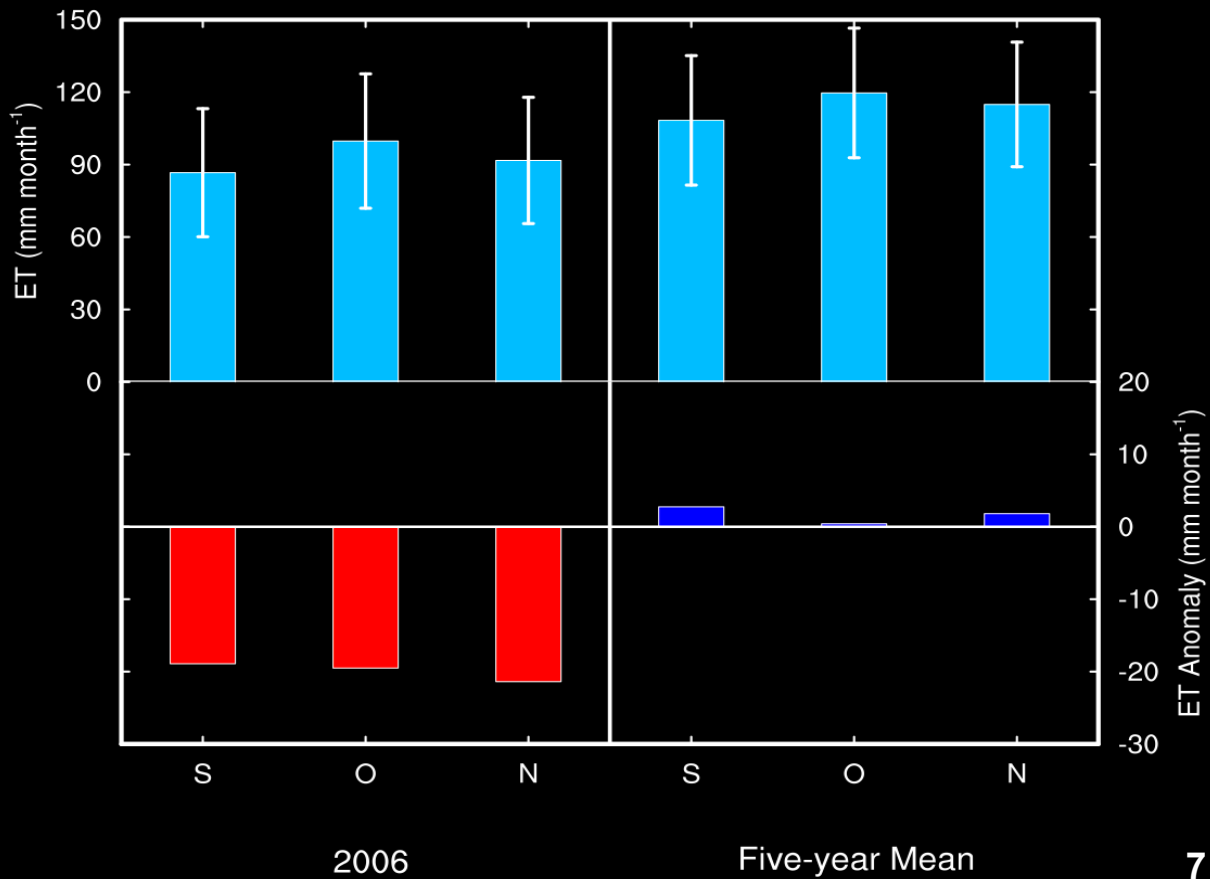
where P is precipitation, R is runoff, S is water storage, and t is time.

This ET product shows reduced ET in 2006 compared to the other base-line years



- Compared to the mean ET in the baseline years, the September, October, and November (SON) ET in 2006 decreases by 20%.
- The observed drought legacy effect on forest triggered ET reduction in 2006.

We calculate the basin area-averaged ET in 2006 and in the five selected baseline years.



Water isotopes

- Stable water isotopes are

Datasets	Purpose
Deuterium retrievals from the Tropospheric Emission Spectrometer (TES)	To separate the ET sources (i.e., local ET or oceanic evaporation) of the baseline years

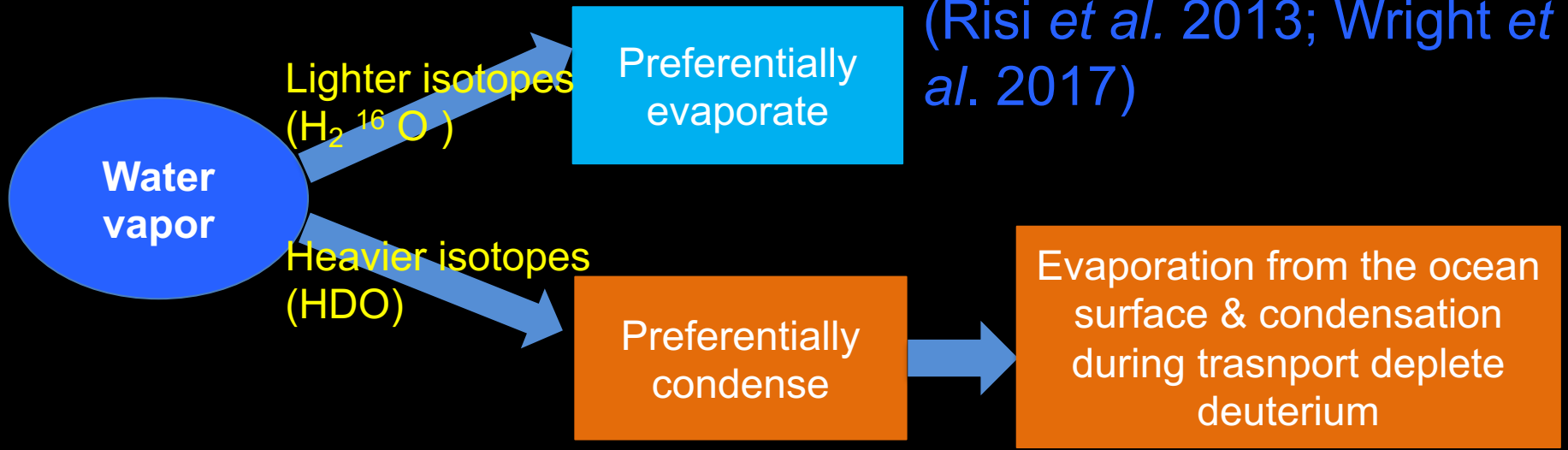
$$\delta D = 1000 \times \left(\frac{R - R_{std}}{} \right).$$

of H_2O molecules and

$R_{std}=3.11\times10^{-4}$

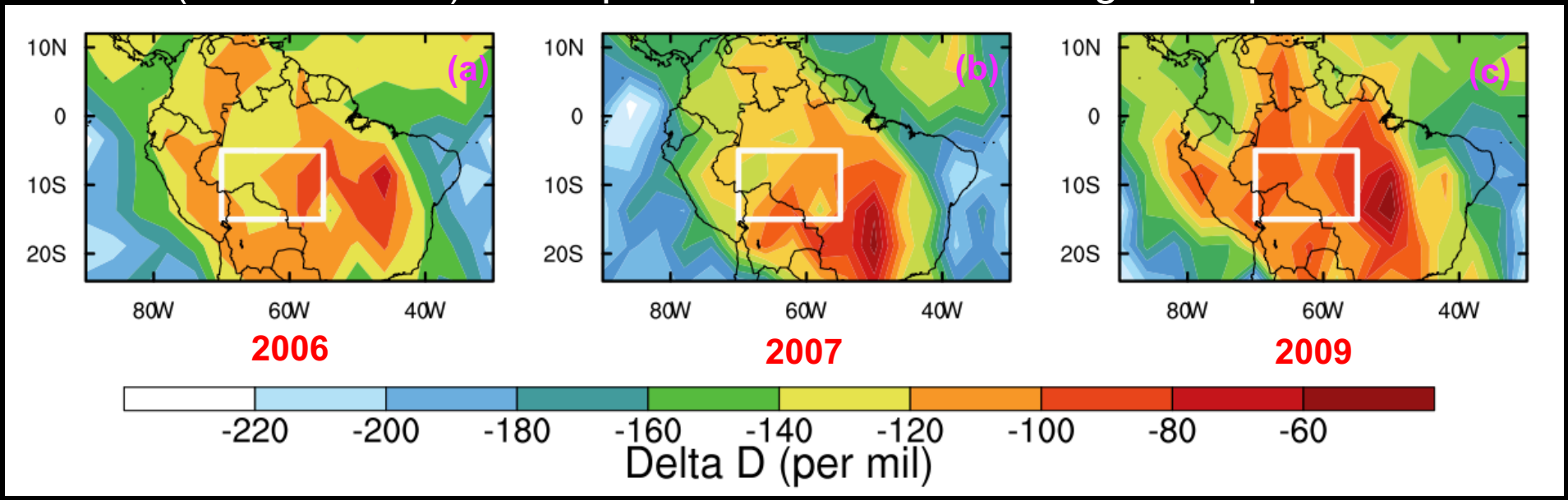
- Molecular differences among common isotopes, such as $H_2\,^{16}O$ and HDO, cause fractionation during most phase transitions:

Tropical ocean: isotopic composition of -70 to -90‰, **Rainforest ET:** 0 to -60‰ (Risi *et al.* 2013; Wright *et al.* 2017)



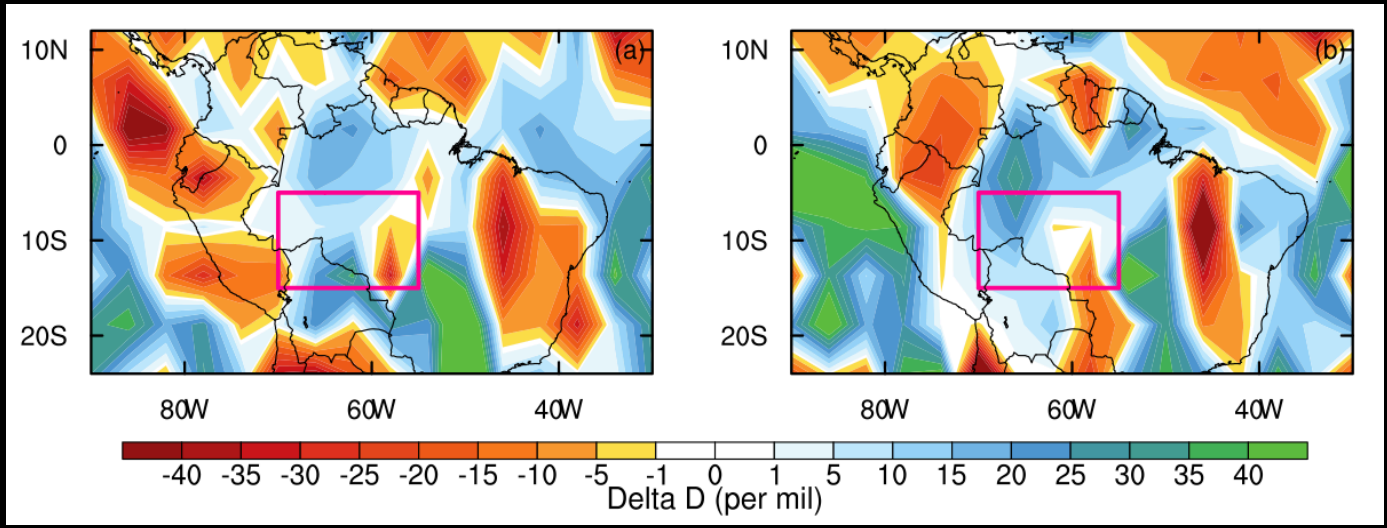
TES observed HDO variations

TES δD (825–600 hPa) is sampled to 4° latitude x 4° longitude spatial resolution.



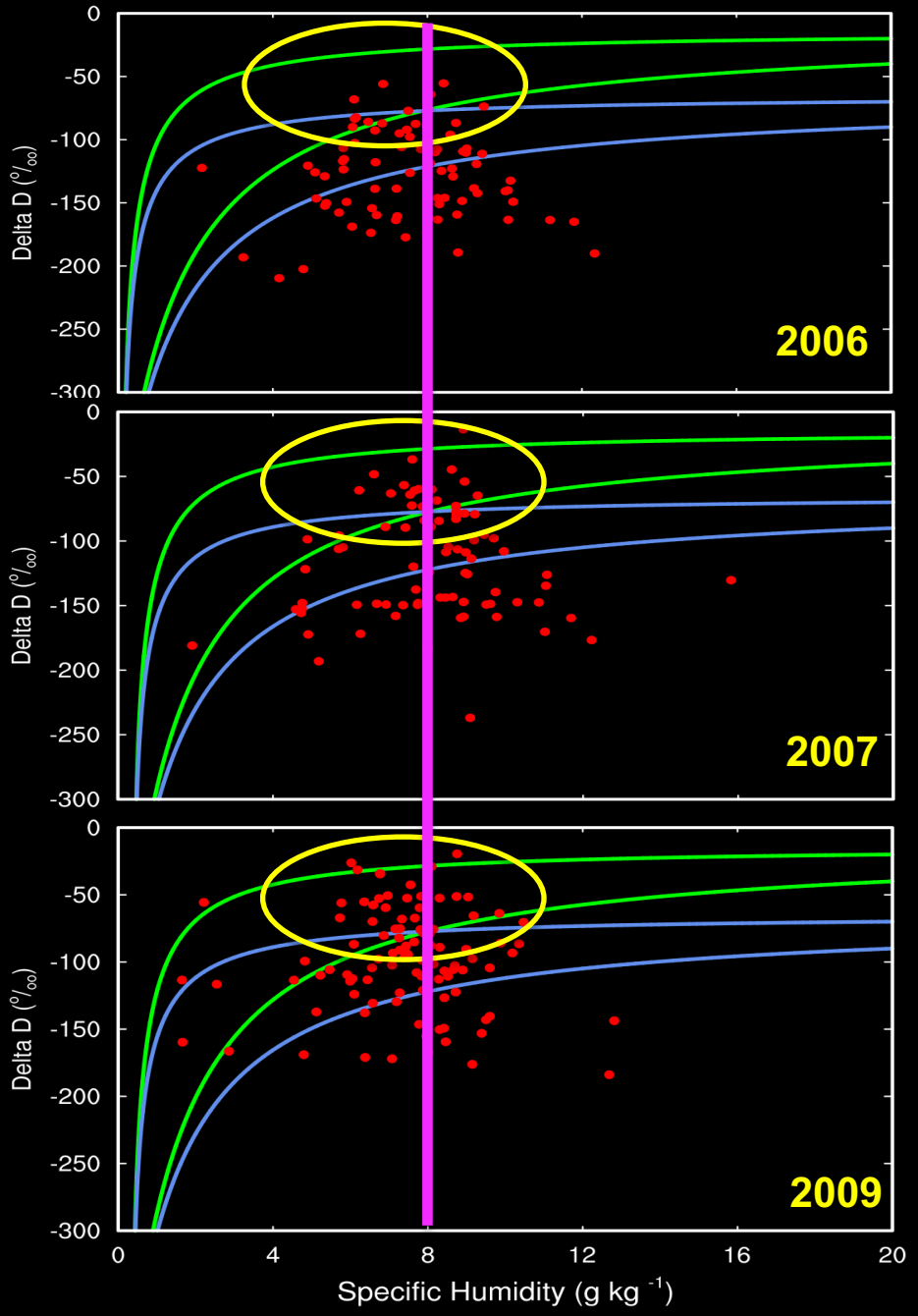
2007 minus 2006

2009 minus 2006



The mean δD value of 2006 (-119.4±9.3‰) is relatively lower to those of 2007 (-110.0±13.1‰) and 2009 (-110.2±8.4‰).

TES observed HDO indicates reduced local ET in 2006



Larger specific humidity is associated with lower δD values in 2006 than in the other two years, as there are fewer observations (i.e., red dots) between the green lines.

ECMWF-ERA 500 hPa vertical velocities:

Year	Unit (Pa s^{-1})
2006	0.012
2007	0.018
2009	0.016
$Mean_{2001–2015}$	0.015 ± 0.003

This result suggests a smaller relative contribution from local ET in 2006.

(Shi *et al.*, GRL, 2019)

Discussion and Conclusions

1) Wet season onset in southern Amazonia is delayed in 2006 as shown by TRMM precipitation.

2) A precipitation, runoff, and terrestrial water storage based ET product shows that ET is reduced in the late transitional stage of 2006.

3) Compared to 2007 and 2009, the relative contribution of local ET to precipitation is reduced during the 2006 late transition.

4) The results in this study imply an important land–atmosphere feedback due to the drought legacy effect.

Acknowledgments

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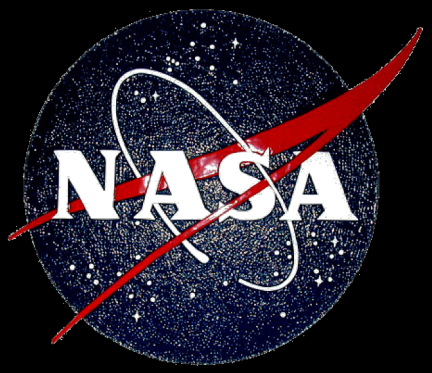

Thanks for your attention!